WEST AFRICAN CACAO RESEARCH INSTITUTE

ANNUAL REPORT

April, 1951 to March, 1952

TAFO, GOLD COAST

Published on behalf of the West African Cacao Research Institute by the Crown Agents for the Colonies, 4, Millbank, London, S.W.1.

1953

Price 5/-

COMMONWEALTH MYCOLOGICAL INSTITUTE
5 AUG 1953

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CONTENTS.

	Managing Committee	page 3
	Staff List	page 4
Section I.	Policy and Organization	pages 5–7
Section II.	Virus Research	pages 7–8
Section III.	Capsid Research	pages 8–11
Section IV.	Soil Science	pages 11–14
Section V.	Chemistry	pages 14–19
Section VI.	Horticulture and Plant Breeding ...	pages 19–27
Section VII.	Mycology	pages 27–28
Section VIII.	Mealybug Studies	pages 28–32
Section IX.	Arboricides	pages 32–36
Section X.	Agronomy	pages 36–50

Appendices.

I.	Meteorological Data ...	pages 51–52
II.	Publications	page 53
III.	Financial Statement ...	page 54

WEST AFRICAN CACAO RESEARCH INSTITUTE.

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WEST AFRICAN CACAO RESEARCH INSTITUTE.

SENIOR STAFF LIST AS AT 31ST MARCH, 1952.

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Division of Entomology	J. NICOL, B.Sc.(For.).
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Division of Soil Science and Chemistry.	J. A. R. MACLEAN, Ph.D., B.Sc., A.R.I.C.
	S. N. ADAMS, B.A., D.Phil.
Division of Agronomy	R. J. BENSTEAD, N.D.A.
	R. WICKENS, B.A., Dip.Agric., D.T.A.
	S. E. NTIM KWAFO.
Maintenance Engineer	C. ALDERSON, D.S.O., E.D., B.Sc., M.Inst.M. and C.E.
Secretary	G. H. NEAL, F.R.S.A., F.I.P.A.

WEST AFRICAN CACAO RESEARCH INSTITUTE.

ANNUAL REPORT : 1st APRIL, 1951 TO 31st MARCH, 1952.

I. POLICY AND ORGANIZATION.

Senior Staff Changes.

The Institute has been fortunate in securing the services of Dr. T. W. Tinsley as Virologist, on secondment for one tour from Rothamsted Experimental Station. Dr. Tinsley assumed duty on 20th November, 1951, and the Institute's thanks are due to the authorities at Rothamsted for making this secondment possible.

Mr. R. Knight was appointed Plant Breeder on the 4th September, 1951.

While several important vacancies on the staff remain, it is encouraging to note that five probationers in training have been designated for the Institute's senior staff. The prospects of securing a full complement of staff appear now to be more promising than for some years past. Three entomologists are due to arrive in 1952 and a Plant Physiologist and a Virologist in 1953.

With the completion of the construction programme, the post of Construction Engineer became redundant and was abolished. Major C. Alderson, D.S.O., who had held that post was reappointed on contract to the new post of Maintenance Engineer with effect from 4th October, 1951.

Managing Committee.

The Managing Committee met at Ibadan, Nigeria, on the 14th and 15th November, 1951, and at Tafo on the 4th and 5th March, 1952.

Mr. W. B. L. Monson, C.M.G., who had been Chairman of the Managing Committee since 10th December, 1947, concluded his term of service as Chief Secretary of the West African Inter-territorial Secretariat and relinquished the office of Chairman. Mr. A. N. Galsworthy, who succeeds Mr. Monson at the Inter-territorial Secretariat, was appointed Chairman in his place by the Secretary of State for the Colonies.

Visitors.

The Institute continued to receive numerous visitors, both from West Africa and from other countries.

On the 1st May, 1951, the Chairman and members of the Gold Coast Swollen Shoot Committee visited the Institute and, a few days later, the Leader of Government Business, the Minister of Health and Labour and the Minister of Agriculture and Natural Resources, paid a visit.

Other visitors included representatives of the cocoa industry of the United Kingdom, of the Medical Research Council and of Commonwealth universities and colleges. Several officers concerned

with cocoa problems from the Department of Agriculture, Nigeria, paid visits to the Institute, including a party of seven Cocoa Survey Officers.

For the first time, visits were organised for two parties of cocoa farmers, chiefs, teachers and students from the Western Region of Nigeria. These visits appear to have been greatly appreciated and thanks are due to the Gold Coast Department of Agriculture who arranged for the accommodation and feeding of these visitors.

Numerous visits by Gold Coast cocoa farmers, teachers and others were organised by the Department of Agriculture.

Scientific Assistance.

The Institute maintained relations with individuals and research organisations in other parts of the world and continued to receive advice and assistance from specialists who are acknowledged authorities on various subjects with which the Institute is concerned. Dr. W. J. Hall, Director of the Commonwealth Institute of Entomology, paid a personal visit in March, 1951, to advise on mealybug problems. The Commonwealth Bureau of Biological Control continues to assist the project for biological control of mealybugs by the collection and shipment of parasites from other parts of the world.

Systemic Insecticides.

The Institute has undertaken jointly with Pest Control Limited a series of experiments with the systemic insecticide CR.409 which has been evolved by the Firm. A report on the progress of this work was presented in a paper read at the 1951 London Cocoa Conference (1).

London Cocoa Conference.

The 1951 Cocoa Conference was held on the 11th-13th September, under the auspices of the Cocoa, Chocolate and Confectionery Alliance Ltd. Seven officers of the Institute attended, including the Director and Deputy Director and five papers concerning the work of the Institute were presented.

Maintenance.

As mentioned above, the Construction Branch has now been replaced by the Maintenance Division, which has also taken over the maintenance work formerly undertaken by the Agronomy Division.

The water supply was put into full operation in April, 1951, and has worked continuously since that date. The filtration plant has been satisfactory and regular examination of water samples by the Government Water Examination Specialist has shown the water to be of excellent quality and free from coliform organisms.

(1) West J. Progress of Research at WACRI on systemic Insecticides Carried Out with Pest Control Limited. London Cocoa Conference Report, 1951.

JUNIOR STAFF RECREATION CENTRE.

The Recreation Centre in W.A.C.R.I. Village was formally opened on the 25th August, 1951, by the Minister of Agriculture and Natural Resources, the Honourable A. Casely-Hayford, M.L.A.

II. VIRUS RESEARCH.

NEW VIRUS STRAINS.

Two more strains of the cacao swollen shoot virus have been added to the W.A.C.R.I. collection. One was collected from the Wenchi—Techiman district (Ashanti) and had symptoms which resembled those of Bosomuosu 2 (Western Province). The other came from Okerikrom—Dormaa (Ashanti) and showed light green mottling along the primary and secondary veins. Swellings were observed on the chupons.

STUDIES IN VIRUS 1A COMPLEX.

Three cacao trees which had been infected with a mild strain of virus 1A by budding in 1945, were tested both for virus content and to determine the number of strains present. These trees had, since the initial infection displayed apparent immunity to subsequent invasion with more virulent strains.

Test specimens were taken from many positions in the canopy. A minimum of 50 test beans was used for each test and the starved mealybugs (*P. njalensis*), were transferred at the rate of one per bean after their infection feed. The results showed that both the mild and severe strains of 1A were infecting these trees though they were not transmitted with equal efficiency. More plants became infected with the severe strain than the mild.

MECHANICAL TRANSMISSION.

Epidermal and apical injections into cacao seedlings were made using sap expressed by water under high pressure from the cut ends of petioles and veins of infected *Adansonia digitata* seedlings. Injections were also made into the radicles of cacao beans. No transmissions were recorded.

CHEMOTHERAPY.

The experiments described in the Annual Report, 1950-51, have been extended. The effects of over 25 chemicals on cacao swollen shoot virus in cacao were tested. Various methods of plant injection were tried in addition to watering the chemicals on to the soil. No effects were observed on either plant susceptibility to infection, the rate of virus multiplication or on the expression of symptoms.

ALTERNATIVE HOSTS.

Investigations into the host range of cacao swollen shoot virus were continued, and in particular the alternative hosts of the severe 1A strain. *Triplochiton scleroxylon,* K. Schum., *Cistanthera papaverifera,* A. Chev., *Desplatzia lutea,* A. Chev., *Cola nitida,* A. Chev.,

Hibiscus esculentus, Linn., *Gossypium* spp. and *Xanthosoma* spp. were again tested with negative results. Species not previously tested included *Manihot utilissima,* Pohl., *Abutilon asiaticum* G. Don., *Datura stramonium* Linn., *Ricinodendron africanum,* Muell. Arg., *Capsicum annum,* Linn. None of these species has so far proved infected. Further work on *Corchorus tridens* Linn. has shown that frequently these plants can be infected and yet show no symptoms.

A wide range of forest trees associated with outbreaks of swollen shoot virus in cacao were tested for virus infection. No transmissions were recorded. The species tested include :—

Bombax buonopozense P. Beauv.
Sterculia Tragacantha Lindl.
Cola nitida A. Chev.
Cistanthera papaverifera A. Chev.
Erythrina altissima A. Chev.
Trichilia Heudelotii Planch.
Ficus asperifolia, Miq.
Chlorophora excelsa, Benth. & Hook.
Alstonia congensis Engl.
Terminalia superba Engl. & Diels.
Kigelia acutifolia Engl.
Bertiera spp.
Parkia filicoidea Weln.
Ceiba pentandra Gaertn.
Sterculia rhinopetala K. Schum.
Triplochiton scleroxylon K. Schum.
Ricinodendron africanum Muel. Arg.
Khaya grandifoliola C.DC.
Ficus capensis Thunb.
Ficus exasperata Vahl.
Funtumia elastica Staph.
Conopharyngia spp.
Celtis Soyauxii Engl.
Lannea acidissima A. Chev.
Albizzia ferruginea Benth.

In addition several forest trees and plants were tested for virus infection as they had leaves showing virus-like symptoms. No transmissions were obtained using *P. njalensis* as a vector. The species were :—

Glyphaea lateriflora Hutch. & J. M. Dalz. *Bombax buonopozense* P. Beauv.
Malacantha Heudelotiana Pierre. *Sterculia Tragacantha* Lindl.
Fleurya podocarpa Wedd. *Mareya spicata* Baill.
Canthium glabrifolium Hiern. *Mangifera indica* Linn.

Two *Bombax buonopozense* seedlings which were infected in 1948 by bombardment with the Offa Igbo strain of cacao swollen shoot virus have since March, 1951, given positive results when they were retested at intervals of two months. All attempts to obtain virus transmissions failed prior to this date, in spite of repeated coppicing. The symptoms expressed in the cacao test plants have increased in intensity at each subsequent back-test.

III. CAPSID RESEARCH.

General.

Macromischoides Plot.

This area is now used principally for insecticide investigations; it has consequently been decided to alter the name of the plot to the " Insecticide Trials Area " and in future Reports it will be so termed.

Early in the year the crop prospects were good but a considerable amount of wilt of the young pods followed a dry spell of weather. The total crop was 1,966 pods of which 8·7 per cent. were damaged by rodents. No rodent control is practised here and creepers which are normally killed throughout the rest of the Station are allowed to grow. Farmers do not usually remove these creepers which form ideal sheltering places for certain squirrels.

Several of the 1/6 acre plots were used for insecticide tests and severe damage occurred in some. The abundant damage in the Control Plots and in some of the treated plots can well explain the drop in the crop when compared with previous years.

These damaged trees are being left to see if they will recover under normal insecticidal treatment.

Macromischoides Area Extension.

These plots are now coming on well after a very slow start and a large section has been lent to the Division of Pathology who have budded the seedlings with budwood from all the remaining trees in the Pilot Experiment to see if some assessment can be made of the virus status of those trees.

Forest Reserve Cacao Plots.

There is little further to report on these plots. The cacao continues to flourish and in some cases the trees are 15-20 feet high. No capsids were seen when the plots were visited and only one tree showed any signs of feeding marks.

Mealybugs were uncommon and only one small colony was seen.

Chemical Control of Capsids.

Machines for applying Kumakate *to young cacao.*

The usual method of applying Kumakate (2·5 per cent. D.D.T. emulsion), i.e., by brush, is convenient and simple for native farmers or where there is not a great deal of young cacao to be treated. In plantations and large farms the time taken for application is considerable and it was thought that a small pressure type sprayer might be adopted which would decrease the time factor.

Small knapsack spraying machines (machine 1) were obtained (one gallon capacity) with reasonably effective trigger valves. The main requirement in the trigger valves is robustness and quick " cut-off " with a minimum of drip.

Later a very well designed hand pressure sprayer holding one quart of solution became available for tests. The air pressure is applied by means of a bicycle or car-type pump and the machine which was used had seen a considerable amount of hard use in various parts of the world. In spite of this it was in excellent

condition and behaved splendidly during the test. Unfortunately it had to be returned before it could be really adequately tested. Others have been ordered and a full report will be included in the next Report.

The results obtained are shown below.

TABLE 1.

Method of application.	Number of trees.	Cost in pence.			Cost per 100 trees.		
		Labour.	Materials.	Total.	Labour.	Materials.	Total.
1. Hand ...	1,462	45	18	63	3·1	1·2	4·3
2. Machine 1 (No swirl plate)	1,471	18	58·5	76·5	1·2	4·0	5·2
3. Machine 1 (Nozzle A)	1,471	12	32·5	44·5	0·8	2·2	3·0
4. Machine 1 (Nozzle B)	1,471	12	36	48	0·8	2·5	3·3
5. Hand ...	1,589	60	15·5	75·5	3·7	1·0	4·7
6. Machine 2	1,606	22	26	48	1·4	1·6	3·0

The above figures are based on a labour cost of 3/- per man per day and a D.D.T. concentrate cost of 24/- per gallon.

It can easily be seen that the use of machines cuts the cost of labour greatly, but except for Machine 2 the consumption of the insecticide increases very much.

As mentioned above several of the No. 2 machines have been ordered and they will be put on an extended test when they arrive.

D.D.T. Dusts and Cacao Pollination.

The use of D.D.T. dust in cacao farms to control capsids in mature cacao is at present considered the best available method.

One of the drawbacks associated with the use of dusts is that a considerable quantity ultimately descends to the ground and it was thought that with a persistent insecticide, such as D.D.T., this portion might adversely affect the pollinating insects of the cacao and thus result in a decreased crop.

An area of healthy, young but bearing, cacao remote from other cacao became available and it was decided to test the above hypothesis.

This cacao which measures about one acre in extent will be heavily dusted every three weeks with 5 per cent. D.D.T. dust. After the first application all open flowers and small cherelles which could be found were removed, the later flowers being left.

Comparison will be made with a similarly aged area of healthy cacao which will, of course, receive no treatment.

Regeneration of Capsid Pockets—Old Station.

The general health of the trees in all the plots has been good and capsid damage kept at a minimum by the use of D.D.T.

Plot G1/2 which was coppiced in October, 1946, and which contains 42 coppiced trees produced 514 pods this year. An average of 12·5 pods per tree five years after treatment can be considered very good especially as the seedling cacao planted at the same time to fill the vacancies in plot have not yet come into bearing.

Regeneration of Capsid Pockets—Square Mile.

This large scale trial has prospered well during the year and the chupons arising from the coppiced stumps are growing with great vigour.

IV. SOIL SCIENCE.

Growth of Cacao in Water Culture.

The object of this experiment was to observe the effect on cacao seedlings of deficiencies of major nutrients, both separately and together. Eight different culture solutions were therefore used. They may be designated NPK, PK, NK, NP, K, P, N, and O—i.e., complete nutrient solution, N-deficient solution, etc.

Methods: Amelonado beans were germinated in washed sand, watered with distilled water and, after 18 days, transferred to glass jars of 700 c.c.s. capacity containing the nutrient solutions. The constitution of the solutions is shown in Table 2. Aeration was provided and the solutions renewed every fortnight. Growth of algae in the jars was prevented by surrounding them with a black paper sleeve. There were 10 replicates of each treatment and the jars were arranged in randomised blocks on a greenhouse bench. Deficiency symptoms were recorded each week. Four blocks were harvested 100 and 150 days after planting and the dry weight of leaves, stems and roots was recorded.

TABLE 2.

Ionic concentration in Culture Solutions (m.eq./litre).

Treatment	NH_4*	NO_3[1]	H_2PO_4[1]	K*	Ca**	Mg**	SO_4[11]	Na*	Cl
NPK ...	1	14	1	6	8	4	4	—	—
PK ...	—	—	1	6	8	4	4	1	14
NK ...	1	14	—	6	8	4	4	—	1
NP ...	1	14	1	—	8	4	4	6	—
K ...	—	—	—	6	8	4	4	1	15
P ...	—	—	1	—	8	4	4	7	14
N ...	1	14	—	—	8	4	4	6	1
O ...	—	—	—	8	8	4	4	7	15

Each solution also contained 1·0 p.p.m. Fe***, 0·5 p.p.m. B, 0·5 p.p.m. Zn,** 0·5 p.p.m. Mn** and 0·02 p.p.m. Cu**.

Results: Mineral deficiency symptoms are summarised below.

Treatment NPK: The controls made rapid growth. By the time the experiment was completed, 150 days after planting, six flushes had been produced and the plants had an average height of 17 inches. At all times, their appearance was quite normal.

Treatment PK: The N-deficient plants made normal growth until the second flush had been produced. After 60 days, however, they were paler than the controls. From this point, practically no progress was made. A third flush was not formed and leaf-scorch appeared at the edges of all leaves at about 100 days, leading eventually to defoliation. All plants were on the point of death at the end of the experiment.

Treatment NK: Apart from being darker than the controls, the P-deficient plants made normal growth until the fourth flush was about to develop after 100 days. From this point only slow growth was made and scorch developed round the edges of the older leaves, leading eventually to defoliation. Transpiration remained considerable to the end of the experiment.

Treatment NP: At 60 days, the K-deficient plants were normal in size but leaf-scorch had already developed round the edges of the first flush. After this, slow growth was made but leaf-scorch and defoliation developed on the older flushes and progressed up the plant. A fourth flush was eventually produced but, by the end of the experiment, the three older flushes had been lost.

Treatments K, P and *O* at no time showed any difference from the N-deficient plants of treatment PK.

Treatment N: After 60 days, the plants of this treatment showed both P and K deficiency symptoms, being darker in colour than the controls and having leaf-scorch round the edge of the first flush. Slow growth continued almost to the end of the experiment and a fourth flush was produced, but leaf-scorch and defoliation removed the first three flushes. As in treatment NK, the leaves were always darker than the controls.

Harvests: The results and analysis of the dry-weight data are shown in Table 3.

At day 100, highly significant effects due to nitrogen and potassium are apparent, particularly in the leaves. Phosphorus, however, had no significant effect on the growth of any part of the plants at this stage. At day 150, effects due to all elements were highly significant.

TABLE 3.

Dry weight and analysis of nutrient effects on cacao grown in water culture.

		100 days Harvest.				150 days Harvest.			
		Whole plant.	Stems.	Leaves.	Roots.	Whole plant.	Stems.	Leaves.	Roots.
(i)	Treatment.								
Mean Weight	NPK	3·74	0·94	2·09	0·72	11·24	3·05	5·96	2·23
(g)	PK	2·12	0·83	0·71	0·59	2·29	0·94	0·57	0·78
	NK	3·36	1·11	1·62	0·62	4·97	2·02	1·49	1·46
	NP	2·68	0·86	1·23	0·58	3·46	1·12	1·40	0·94
	K	2·31	0·89	0·76	0·66	2·27	0·90	0·53	0·84
	P	2·08	0·77	0·69	0·62	2·37	0·79	0·66	0·92
	N	2·66	0·83	1·15	0·67	2·64	1·09	0·57	0·98
	O	2·06	0·75	0·71	0·59	2·12	0·79	0·53	0·80
(ii)	Effect.								
Analysis	N	15·5**	2·0*	12·9**	0·6	53·1**	15·5**	28·6**	9·1**
of	P	1·0	−0·7	1·9	−0·2	29·2**	4·4	21·8**	3·1*
Effects.	K	8·3*	2·2*	5·6**	0·4	40·8**	12·5**	21·6**	6·7**
	NP	2·3	−0·4	2·5	0·2	27·2**	4·1	20·5**	2·7*
	NK	5·9*	0·6	5·0**	0·3	40·2**	10·4**	22·3**	7·5**
	PK	0·6	−1·1	1·5	0·3	20·8*	4·1	14·2**	2·5
	NPK	2·2	−0·6	1·6	1·2	22·7**	3·9	14·9**	3·9**

The effects have been computed by the method of Yates (2). For example, effect of N = (NPK−PK) + (NK−K) + (NP−P) + (N−O), where NPK is the mean plant dry weight of treatment NPK, etc.

Significant effects asterisked. * = $P<0{\cdot}05$; ** = $P<0{\cdot}01$.

Discussion: As far as is known, no symptoms of major nutrient deficiency have been seen in the field on Gold Coast cacao. Yet high responses to phosphate have been observed in annual crops grown on the forest soils (1). In this connection, the relative resistance to phosphorus deficiency of the water culture seedlings is noteworthy. The nitrogen- and potassium-deficient plants made little growth after day 60, whilst those lacking phosphorus alone did not show actual symptoms until after day 100. The symptom of mild phosphorus deficiency, a darkening of the leaves could easily be overlooked in the field.

EFFECT OF PHOSPHATE ON BEARING CACAO.

The object of this experiment was to investigate the response of mature cacao to phosphatic fertilizers.

A randomised block design was employed; rock phosphate, superphosphate and double superphosphate being applied at levels of 0, ½ lb. and 1 lb./tree/year. There were three replicates of each treatment, giving a total of 27 plots. Each plot contained 16 trees. The fertilizer was applied every six months—in April when the main crop was setting and in October when the pods were reaching maturity—by broadcasting in a circle of 2 ft. radius round each tree. The leaf litter was scraped away immediately before treatment and replaced afterwards. The cacao used was 20-30 year old, peasant-planted

Amelonado growing on Nankese series, a brown slope soil derived from hornblende granodiorite.

Treatment commenced in April, 1951. It would be premature to discuss results based on only one year's harvest.

PERFORMANCE OF CACAO ON DIFFERENT SOIL TYPES.

Soil profile samples to a depth of six feet have been taken from the 25 plots of this Agronomy Division experiment. The object is to relate soil factors to cacao performance. A detailed soil analysis is being carried out but is not yet completed.

REFERENCES.

(1) Nye, P. H. (1952). Empire J. Expt. Agric.: **20,** 47–56.

(2) Yates, F. The Design and Analysis of Factorial Experiments. Imp. Bur. Soil Sci. Tech. Comm. No. 35, p. 14–18.

V. CHEMISTRY.

1. Laboratory Fermentations and Assessment of Quality.

During the period under review experiments have been directed towards improvements in the methods previously described. The main criticism of the oven fermentation method, for example, has been that pulp from Amelonado cacao is used to ferment the contents of single pods of other cacao types. It has been found that the removal of added dextrose and pulp does not have a deleterious effect on the resulting product. In five replications of a randomised block lay-out incorporating the following treatments:—

A. Dextrose + pulp " starter ",
B. Pulp " starter " only,
C. Dextrose only,
D. No dextrose, no pulp " starter ",

there was no significant difference in the percentages of fully fermented beans from any of the treatments; in all instances 90 per cent. was obtained. Using the incomplete block assessment method previously described (1) a local panel of four, tasting unsweetened liquors prepared from the products of the above treatments, produced the following results:—

A	B	C	D
4·82	4·82	5·05	5·28

($\pm$0·28)
(P 05 = 0·78)

A minor improvement in the apparatus is the use of a constant-level head which ensures uniform displacement of moist air into the bean mass. At a rate of 3 litres per 24 hours the moisture content of Amelonado beans at the end of a six-day fermentation is invariably

greater than 20 per cent., a figure at which cacao oxidases are said to act readily (2).

Attempts to devise suitable methods for the assessment of quality of the products of small-scale fermentations were continued. A method was sought which would be statistically sound and which necessitated the tasting of only a small number of samples at any one session. The most suitable procedure so far found which can be applied to a small series of samples, is the incomplete block design, in which samples are arranged in pairs and each sample is matched against every other sample by each taster. Scoring is by pair differences, each taster being asked to distribute ten points between the pair of samples under test, e.g., if the samples are judged to be of equal value, five points are allotted to each, the pair difference here being zero. The order of tasting is at random, as also is the distribution of the pairs to each taster. Using this method and a local "taste panel", comprising officers of the Institute, results obtained using other statistical methods were confirmed, viz.:—

(*i*) no difference between under-fermented and fully-fermented beans in W.A. Amelonado, T60 (Parinari × Nanay) or Gold Coast selection E1,

(*ii*) the marked inferiority of the Upper Amazon selection compared with the other two selections.

Experiments carried out by this technique showed, in addition, that an increase in roasting time removed the significant difference between Amelonado and the Upper Amazon selection, a point of particular note when this and other Upper Amazon selections are on trial for acceptance by chocolate manufacturers.

The results of an experiment which illustrate the above points clearly are given in Table 4. The samples of the types of cacao used were drawn from basket fermentations of 40 lb. wet beans.

TABLE 4.

	Series I. Standard roast (55 mins.)		Series II. Length of roast.		
	Under-fermented.	Fully-fermented.	50 mins.	60 mins.	70 mins.
W.A.A.	5·56	5·22	5·20	5·27	5·13
T60	4·11	4·00	4·33	5·27	4·80
E1	5·61	5·50	—	—	—
S.E. of a difference ...	±0·607	—	±0·445	—	—
Significant difference P = 0·05	±1·207	—	±0·886	—	—

Using the same panel of tasters and a randomised block design, it is of interest that the products of (i) oven and (ii) large-scale (1,000 lb. approx. wet beans) fermentations of Amelonado cacao showed no significant difference in quality assessment. Samples were tasted in lots of three on four occasions and, scoring on a 0 to 10 basis, the results were as follows :—

TABLE 5.

Taster. \ Sample.	Fair Fermented Accra.	W.A. Amelonado		Mean.
		Oven-fermented pricked beans.	Oven-fermented unpricked beans.	
1	6·25	5·25	6·00	5·83
2	6·25	6·75	5·25	6·08 (±0·370)
3	4·75	6·25 (±0·641)	5·00	5·33
4	5·25	6·25	5·00	5·50
5	6·50	7·25	7·75	7·17
Mean	5·80	(±0·287) 6·35	5·80	—

Significant difference (P=0·05) = ± 0.819

Detailed results on both the above subjects are reported in two papers (3, 4) which were read at the London Cocoa Conference in September, 1951. A further development in the problem of quality assessment has been the use by the W.A.C.R.I. taste panel of a method in which subjective reactions to liquors prepared by a standard procedure are recorded by placing a tick in the appropriate columns of the following table :—

TABLE 6.

Strength of character.	Chocolate flavour.	Astringency.	Bitterness.	Acidity.	Ester-like flavour.	Other objectionable flavours.
V. Strong						
Strong						
Medium						
Weak						
V. Weak						
Absent						

The advice of British and American assessment panels is being sought both on the schedule and the values which should be assigned to each of the above factors; the advantages of agreement on a standardised assessment procedure are too obvious to need stressing.

2. Chemistry of " Black-Pod " Beans.

Previous work on this subject at W.A.C.R.I. (4) showed that the free fatty acid content of infected beans was appreciably higher and the alkaloidal content significantly lower, than the corresponding values for unfermented, healthy beans. The results of a more detailed examination of the nitrogenous constituents suggest the possibility that the fungi invading the beans utilise the xanthine base nitrogen. These results are given below and were obtained from the beans of ripe, healthy W.A. Amelonado pods inoculated in (*a*) the field and (*b*) the laboratory with aqueous spore suspensions of *Phytophthora palmivora* Butl.

Forty pods so infected and an equal number of healthy pods were used in each of five replications and the contents of four pods in each category were bulked for each replication.

TABLE 7.

TABLE OF MEANS.

Percentages are expressed on the wt. of moisture-free, shell-free cotyledons.

Material.	% Reducing sugars.	% Sucrose.	% Total N	% Protein N	% Alkaloidal N (Calc. on theobromine).
Healthy beans (Controls) ...	0·08	2·01	2·32	1·65	0·50**
Laboratory-infected beans ...	0·05	0·85	2·29	1·58	0·33
S.E.	±0·065	±0·100	±0·059	±0·942	±0·027
Healthy beans (Controls) ...	0·10	2·38	2·28	1·62	0·48
Beans from pods infected *in situ*	0·29	0·88	2·11	1·61	0·38
S.E.	±0·096	±0·101	±0·059	±0·033	±0·028

** Significant at P = 0·01.

The pH of infected beans varied from 6·0 to 7·6 and it was found that inocula from these beans grew profusely on agar slopes of cassava starch + theobromine buffered to pH 6·0, for example, whilst little or no growth occurred in the same period on the same medium minus a nitrogen supply.

3. Herrania Spp.

The most important results of preliminary chemical analyses of the beans from three *Herrania* spp. [*H. balaënsis, H. Mariae* and *H. Sp.* " B " (at present unidentified)] are

(*i*) the high fat content (63-65 per cent. on moisture-free, shell-free material), and

(*ii*) the caffeine content (0·6-0·8 per cent. on oven-dried fat-free powder) with some samples 1·0 per cent.

The freshly extracted fat from all three species is liquid at laboratory temperatures (25°–30° C.), solidifying over a period of days to a soft fat, mp. = 33°–35° C. The free fatty acid content of the oil (2–3 per cent.), the Iodine values (39–47), and Saponification values (203–206) are all slightly higher than those for cacao butter, which is in addition a hard brittle fat. It is unlikely to be of use in chocolate manufacture but may be a source of edible oil. More detailed results have been published in " Nature " (5).

4. Examination of Cacao Pulp.

This work forms part of a study (with the Agronomist) of the relationship of pulp sugars to other factors associated with cacao fermentation and has centred on the reducing sugar and sucrose content of pulp

(*a*) from various cacao types at different degrees of ripeness and stored for periods varying from one to four days between harvesting and breaking, and

(*b*) during basket fermentations of different cacao types.

A relationship appears to exist between the percentage of purple beans in basket fermentations (40 lb. wet bean batches) and the reducing sugar content of the pulp, the batches producing the highest purple bean percentage having the lowest reducing sugar content. It is also of note that pulp from under-ripe pods contains a significantly lower reducing sugar content than that of ripe or over-ripe pods.

5. Chemical Problems Relating to the Cacao Viruses.

Paper chromatography is being applied to various tissue extracts and saps of *T. cacao* and a number of alternative host trees of cacao viruses in an attempt to discover differences in the qualitative composition of healthy and virus-infected tissues. Initial analyses are being confined to amino-acids, organic acids and carbo-hydrates. The secretions from mealybugs feeding on those tissues are being similarly examined. This work forms part of a joint approach, with the Plant Pathologist, to the problems of multiplication of cacao viruses in *T. cacao* and alternative hosts and the results may have a bearing on mechanical transmission and serological work in progress.

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VI. HORTICULTURE AND PLANT BREEDING.

VEGETATIVE PROPAGATION.

ROUTINE PROPAGATION.

Propagation of E1 for Department of Agriculture.

The production of rooted cuttings of the clone E1 has now stopped as the Department of Agriculture has set up its own propagation units. A total of about 6,000 plants has been supplied to the Department since the work started.

Plant Breeder's Selections.

Clones are being established of a number of selections made by the Plant Breeder, and it is evident from this work that, apart from the variation in rooting response due to the condition of the parent plant, there is an inherent difference in the rooting potentiality of the different selections.

Selections for Nigeria.

Selections required by the Department of Agriculture, Nigeria, have been propagated successfully under quarantine conditions in Accra. The propagators employed were of the low wooden type described in the previous Annual Report. The bin lights were covered with muslin, which was kept damp, whilst the Quarantine House was damped-down four times daily to counteract the low humidity which prevailed.

The parent cuttings were all taken at the same time and grown under the same conditions; as far as could be judged they were all equally healthy and vigorous at the time the propagating material was taken from them. In spite of the uniformity of this material there was a wide range of rooting response amongst the cuttings. Table 8 shows the numbers of cuttings of each selection which rooted.

TABLE 8.

Month set.	Selection.	Type.	% rooted.
February 1952	T60/764	Upper Amazon	35
,,	T12/26	,, ,,	67
,,	T60/961	,, ,,	22
,,	TF1/116	Local hybrid seedling	16
,,	E1/70	,, ,, ,,	78
,,	K5/353	,, ,, ,,	29
April	T9/67	Upper Amazon	40
,,	T12/26	,, ,,	89
,,	TF1	Local hybrid clone	89
,,	E1	,, ,, ,,	74
,,	TF1/116	,, ,, seedling	45
,,	T12/26	Upper Amazon	80

During February the relative humidity in Accra was extremely low and conditions were most unfavourable for propagation. In spite of this E1/70 and T12/26 maintained high rooting percentage.

Variation in rooting response of clones in routine propagation.

The percentage rooting responses of all selections used for routine propagation were calculated for the period September, 1950, to March, 1952, and are shown in Table 9. These data represent cuttings which had adequate root systems for potting by the end of one month and does not include those with roots just emerging. As the cuttings not rooted or with only small root systems are discarded at the time of potting, these data do not represent the full rooting response of the selection but the speed of rooting shown by that selection.

TABLE 9.

Selection.	Type.	% rooted.
E1	Local Hybrid	56·2
TF1	,, ,,	76·0
ICS1	Trinitario	53·0
A196	Selected Amelonado	37·0
N38	Nigerian Hybrid	27·0
S72	Amelonado	6·0
S84	,,	24·5
B2	Trinitario type	41·0
P4/9	Selected Amelonado	13·0
K5	Local Hybrid	70·0
Amelonado (selected)	—	33·0
A45	Local Hybrid	14·0
T60	Upper Amazon	67·0
Amelonado (unselected) ...	—	55·0
Na 32	Upper Amazon	82·0
Pa 35	,, ,,	79·0
U11	Local Hybrid	54·0

Allowance must also be made for the wide variation in the vigour of the parent trees, which has a marked effect on the rooting response.

Clonal Nursery.

One of the main difficulties in vegetative propagation has been the necessity of taking the propagating material from old, bearing or weakly trees.

A clonal nursery has now been started on about 1¼ acres of land which has been under food crops for some years. The soil is mainly Nankese series: there is no existing shade.

Gliricidia stakes have been planted at 8 ft. × 8 ft. throughout the plot interspersed by tree cassava (*Manihot glaziovii*) at 4 ft. × 4 ft. to provide nurse shade for the first two years.

As soon as the tree cassava has started into growth 24 rooted cuttings of each selection, of which it is desired to establish a clone, will be planted at 4 ft. apart in the pure cassava rows, i.e., giving an 8 ft. × 4 ft. stand. Watering will be done as necessary and heavy mulching with Napier fodder will be carried out to preserve soil structure and moisture and to smother out the grass.

EXPERIMENTAL PROPAGATION.

The importance of leaves to the cutting.

An experiment was carried out in which five-leaf fan shoots of clonal material were divided into cuttings each possessing three leaves: there were thus three types of cutting—

(*i*) with apical, second and third leaves,

(*ii*) with second, third and fourth leaves,

(*iii*) with third, fourth and fifth leaves.

In each type one-third of the cuttings had the basal leaves removed whilst another third had the two basal leaves removed, the remainder retained three leaves. The cuttings received normal cultural treatment. The results are shown in Table 10.

TABLE 10.

Influence of number of leaves on rooting response.

Number of leaves.	Mean total root length per cutting.	Mean root number per cutting.	Number of cuttings rooted.
1	22·17	3·98	44
2	*38·34 ± 4·81	*6·82 ± ·863	53
3	*40·16	*6·81	54

* Significant P = 0·05, n = 32.

TABLE 11.

Influence of position of cutting.

Position.	Mean total root length per cutting.	Mean root number per cutting.	Number of cuttings rooted.
1	31·98	5·34	49
2	31·76 ± 4·81	6·12 ± 0·86	52 ± 3·75
3	36·94	6·15	50

From Table 10 it is evident that the difference in rooting response and root quality between cuttings with one leaf and cuttings with more than one leaf is considerable, whilst the possession of more than two leaves confers no greater advantage. The varying ages of the tissue at the base of the cutting have little or no effect upon the rooting response (Table 11). In view of these findings two-leaf cuttings have been adopted for routine propagation. A further advantage has shown up in that the two-leaf cuttings start into growth far more rapidly than either complete fan shoots or single-leaf cuttings.

Assimilation/Respiration Balance during Rooting Period.

Continuation of the dry weight determinations on single-leaf cuttings reported in the report for 1951 showed that the assimilation/respiration balance followed a course which explained to a large extent the failure of many cuttings halfway through the rooting period.

A total of 1,500 cuttings was used in a series of four experiments. In analysing, the regression of the dry weights on time was calculated and the corrected weights obtained from the regression equation were used to calculate the dry weight at each sampling as a percentage of the initial dry weight.

The results showed that up to the end of the first two weeks there was a steady increase in respiration compared with assimilation and the cutting as a whole lost weight. This loss was solely from the leaf, the stem gained steadily. After this time there was a steady reversal of the balance and by the end of one month the cutting in some cases had exceeded the initial weight.

It is obvious from these results that if the initial nutrient reserves of the cutting are too low then by the end of the second week in the rooting bins they will have been almost completely exhausted and the second phase of recovery will not take place. From a practical viewpoint it is therefore of great importance to ensure the use of the best propagating material and to reduce as much as possible, by manipulation of the environment, the respiration loss from the cutting in the rooting bins.

PLANT BREEDING.

Established Trials.

The existing field trials were maintained and recorded throughout the year. In the " First Progeny Trial " only the yields of the six best selections were recorded. The yields in the " Second Progeny Trial " have been influenced by capsid damage, pod stealing and the hand-pollination programme. It is most unfortunate that hand-pollinated pods were too often stolen from the trees. In the " Introductions Area," apart from stealing, there was a loss of pods from squirrel damage which was later reduced by the use of poison bait.

Every effort was made during the year to obtain well fermented samples from as many selections as possible. Small numbers of pods from each selection were fermented by the Chemist for later testing by the " local taste panel." The Agronomist received a larger number of pods for fermentation and subsequent quality testing in the U.K. and U.S.A. Details of the methods used and the results obtained will appear under the appropriate sections.

1st Progeny Trial.

The 1st P.T.A. is now twelve years old. The yields of the six selections recorded during 1951-52 are expressed as yields per acre as a guide to performance but it is emphasized that there are dangers in the computation of this figure. It is pointed out that each selection is represented in each quarter-acre by only three trees in a line and thus there is no indication as yet of the performance of a selection if planted in large blocks.

During the year two trees were removed from the 1st P.T.A. through swollen shoot disease. Twenty trees have now been removed from this trial since the first symptoms were recorded in 1948. The number of trees in the trial is 4,400.

TABLE 12.

Selection.	Number of trees.	Mean number pods/tree.	Mean wet wt./pod (oz.).	Computed dry weight per acre.
E1*(1)	117	18·63	4·32	804
N38*	121	15·66	3·68	576
S72	118	13·25	3·87	513
A196	121	13·33	3·28	437
S84	117	11·79	3·51	414
P4/9	118	9·22	3·43	316

* E1 and N38 are ' hybrid ' types.

2nd Progeny Trial.

The trees in the 2nd P.T.A. are 10 years old. The yields of the better selections are given in Table 13. Again the yield of dry

cocoa per acre is a computed figure, given as a guide to performance of a selection. It is of interest that the yield of E1 selection in the 2nd P.T.A. at 10 years is almost the same as its yield in the 1st P.T.A. at 10 years.

One tree was removed from this trial through swollen shoot disease. Three trees have been removed from the 2nd P.T.A., since symptoms first showed in 1948, out of a total of 3,280 trees in the trial.

TABLE 13.

Selection.	Number of trees.	Pods/tree.	Weight wet/pod ozs.	Computed dry weight per acre.
TF1	77	13·94	4·3	599
E1	79	13·94	4·2	585
U11	79	11·28	3·9	440

ALBINO PLOT.

The Albino Plot came into bearing for the first time during the 1951–52 season. This plot was budded in 1946/47 and consists of a 6 × 6 square of trees which produce albino seedlings when selfed. First results indicate that cross-pollination has taken place over the whole plot. Consequent upon this finding, a larger albino plot of 13 × 13 trees has been budded in another area.

CLONAL TRIALS.

It was reported in the Annual Report, 1950-51, that the clonal trials would be thinned on a quincunx basis. During 1951 the trees were cut back but not removed. On further observation it was decided not to thin these trials at this stage and the pruned trees have been allowed to grow.

The " First Clonal Trial " was planted in 1947 and Second Clonal in 1948 at 10 ft. and 8 ft. spacings respectively.

1st Clonal Trial.

Selection.	Number trees.	Number pods.	Mean number pods/trees.
S27	87	518	5·95
ACU85 ...	92	351	3·81
A12	91	287	3·15

2nd Clonal Trial.

Selection.	Number trees.	Number pods.
TF1	92	87
R15	96	68
A56	95	41

The " hybrid " selection E1, which holds top position in the Progeny Trials, has a very low yield as a clone in the two clonal trials. This is of importance where clonal blocks are being built up for seed production and consequently tests are being made on the setting capacity and compatibility of the parent material E1.

Introductions.

The yields of the Upper Amazon introductions continue to increase. T60 is now bearing on an average 75 pods per tree, an increase of five pods per tree over last year. Similarly, T12 has increased by 14 pods per tree to an average of 62 pods. T63, on the other hand, has shown a decrease of yield from 48-43 pods. This falling off may indicate that the yields of these trees are nearing their maximum. Fermented bean samples of all the more important selections have been sent to U.K. and U.S.A. for quality reports.

One tree (Nanay × Trinitario), Stand 205, was removed from the " Introductions " area with swollen shoot. This is the only case so far recorded in the ten acres.

Species Area (planted 1945).

The first natural set of *Theobroma grandiflorum* was harvested during the year. All the (19) beans germinated and have produced vigorous plants. It would appear that the species of *Theobroma* are reaching a critical age for commencement of flowering and setting.

Pollination Programme.

The pollination programme for the year, comprising some 11,000 hand-pollinations, was designed to elucidate several short-term genetical problems and also to commence the long-term breeding programme. As a foundation for the breeding programme an effort is being made to record as completely as possible a number of botanical characters from each selection. For this purpose a record sheet has been designed as shown on page 26 (Fig. 1).

(a) *Compatibility.*

(*i*) The cross-compatibility between Amelonado, " Hybrid," and Upper Amazon selections was tested and all were found to be cross-compatible.

(*ii*) The three *Herrania* species were found to be fully self- and cross-compatible.

(*iii*) Amelonado × *Herrania* gave a high proportion of sets. *Herrania* × Amelonado was found to be incompatible. An investigation into the causes of this reciprocal difference forms a part of the cyto-genetical programme.

(*iv*) A programme of selfing, crossing with other stands of same type, crossing with Amelonado and crossing between " species " was carried out. As this work overlaps the period covered by this Annual Report, a fuller discussion will appear at a later date.

(*v*) Trees of the selection N38 which had been recorded as self-incompatible in previous years were retested and all were found to be self-compatible.

(*vi*) E1 selection was retested and 17 trees of the 80 under test have now been found to be self-incompatible.

(*vii*) All TF1 and TF2 trees tested were found to be compatible.

FIG. 1.

SPECIES		TYPE	SELECTION
AREA	STAND	TREE AGE	DATE
A. STAND	1. General Shape		
	2. Height	3. Branching Primary	
		4. Branching Secondary	
	5. Chupon Above/Below Jorquette	6. No. Fan Branches at Jorquette	
B. TRUNK	7.		
C. PETIOLE	8. Texture	9. Length	10. Thickness
LEAF	11. Pulvini		12. Leaf Scar
	13. Phyllotaxy		14. Stipules
	15. Upper Surface		
	16. Lower Surface		
	17. Veining		
	18. Shape Juvenile		
	19. Mature		
	20. Leaf Colour	21. Flush Colour	
D. FLOWERS	22. Position	23. Number/Cushion	24. Size
	25. Guide Lines		
	26. Sepal Colour	27. Ovary	
	28. Ligule Length	29. Ligule Colour	
	30. Stamen Colour	31. Anther Number	
	32. Staminodes		
	33. Style		
E. POLLEN	34. Shape	35. Size	
	36. Surface		
F. POD	37. Type		
	38. Colour		
	39. Length	40. Diameter at.....per cent. from base	
	41. Surface		
	42. Ridges		
	43. Neck		
	44. Point	45. Number/Cushion	
	46. Length Stalk	47. Position	
	48. Thickness Shell	49. Hardness Shell	
G. BEANS	50. Surface Colour	51. Markings	
	52. Shape		
	53. Colour Mucilage		
	54. Colour Cotyledon		
	55. Convolutions		
	HERBARIUM NUMBER		

(b) *Cytology.*

Chromosome counts were made on root-tips cut at 10μ, pre-treated with α Bromo-napthalene.

Th. cacao (Hybrid E1)	2n = 20
Th. cacao (Upper Amazon T60)	2n = 20
Th. bicolor	2n = 20
Th. obovatum	2n = 20
Th. microcarpum	2n = 20
Th. grandiflorum	2n = 20

The treatment of beans and seedlings with colchicine has continued without success.

(c) *New Plantings.*

Pollinations were made and the beans resulting were planted in baskets in preparation for a new progeny trial to be known as the 8th P.T.A. The new trial has been designed to test the relative performance of the following groups :—

1. Unselected Amelonado.
2. Selected Amelonado.
3. Local " Hybrids."
4. Upper Amazon types.
5. Amelonado × Upper Amazon.
6. Hybrid × Upper Amazon.

The trial will consist of 36 tree plots (6 × 6) in randomised blocks with four replications.

Nomenclature.

For the purpose of plant-breeding trials, the following code has been adopted for selected material :—

Prefix	WA	Amelonado type.
„	WB	" Hybrid " type.
„	WC	Criollo type.
„	WD	Trinitario type.
„	WE	Upper Amazon type.
„	WAE	Crosses A × E, etc.

The number " 1 " to be reserved for unselected controls.

VII. MYCOLOGY.

The work of the mycology section has been concentrated on comparative fungicide trials to control diseases of cacao pods and on detailed investigations of pod diseases.

Pod Disease Control.

The objects and design of these experiments are to be found in the 1948–49 Annual Report. It is unlikely that any further useful information can be obtained from the experiments in their present form. The results of four seasons' observations are being analysed by statistical methods.

Pod Disease Investigations.

These experiments were started in 1949 and the records show that about 10 per cent. of the harvestable cacao has to be discarded. Rather more than half of this loss is due to damage by *Phytophthora palmivora.* Rodent damage can amount to as much as 25 per cent. of the total pods discarded. Other factors such as boring insects, capsids and minor fungus diseases account for losses in total harvest of 2½ per cent. approximately.

Systemic Fungicides.

The preliminary experiments on the effects of three systemic fungicides on the fungus *Calonectria rigidiuscula,* have proved inconclusive. The fungicides used were Pentachlorophenoxy-acetic acid, Pentachlorophenoxy-iso-butyric acid and 2.4.6. Trichlorophenoxy-acetic-acid. This work is to be continued.

VIII. MEALYBUG STUDIES.

Mealybug Populations on Cacao Trees.

Strickland (1) gives figures showing the numbers of mealybugs found on a normal cacao tree population. These figures emphasise the wide variation which can be found on healthy trees growing in a continuous area.

To see if the mealybug numbers on trees recently infected with swollen shoot bear any resemblance to those obtained by Strickland, counts are being made of the mealybug present on the trees cut out in the Old Station at Tafo. These trees are cut out very soon after symptoms appear and they are normally trees with a good canopy.

As can be seen the figures to date show close similarity to those obtained earlier.

TABLE 14.

Mealybugs.	Strickland's data.		Present data.	
	Number of trees.	Percentage.	Number of trees.	Percentage.
0— 24	536		152	
25— 49	84	81·1	17	83·0
50— 99	80		17	
100—199	69		23	
200—399	50		9	
400—799	29	18·9	2	17·0
800—upwards	16		4	

It is obvious that the vast majority of trees carry small numbers of mealybugs and only rarely are the numbers in excess of 1,000.

Mealybugs and their Ant Attendants.

Owing to the fact that the ants found attending the Pseudococcid mealybugs appear to prefer them to other scale insects it has been frequently suggested that the honeydew they secrete probably contains a substance, or mixture of substances, giving what would almost amount to a specific attraction to the ants.

Conversely several other species of ants which are usually considered harmless or even beneficial do not seem to be attracted by mealybug honeydew, although they tend and foster other types of scale.

This being so there would seem to be a good chance that a poison bait could be developed if this attractive principle could be isolated and chemically duplicated. Such a poison bait could be used to exterminate the harmful mealybug attendants leaving the others unharmed.

Experiments have been started to investigate the question of the attractiveness of the honeydew to the mealybug attendants and to the other scale-attending ants. Comparative tests using honeydew and other attractants such as live mealybug colonies, dead mealybugs and simple sugar solutions are in progress, but no results are yet available.

Biological Control of Mealybugs.

Indigenous Natural Enemies.

From 3,600 mealybugs collected in the Eastern Province of the Gold Coast for investigations on their natural enemies over 300 parasites and predators have been reared. The majority of these were internal parasites of the family Encyrtidae (Hymenoptera) but predaceous Cecidomyiidae (Diptera), Coccinellidae (Coleoptera) and Lepidoptera of the families Lycaenidae and Tineidae were also present. A few parasites and predators have also been reared from Coccidae other than mealybugs.

1,864 predators and parasites have been received from Nigeria during the year and all have been identified except the Cecidomyiidae and a few representatives of uncommon species not yet represented in the W.A.C.R.I. collection of named specimens.

Part of a collection of insects which was sent to the Commonwealth Institute of Entomology for identification has been returned with determinations. It includes nine species of Coccinellidae predaceous on mealybugs and three preying on aphids, and two species of Lepidoptera with coccid-eating larvæ. Three species of Cecidomyiidae with predaceous larvæ have also been identified by Dr. A. Earl Pritchard of the University of California.

Introductions of Exotic Parasites.

The following species of parasites, received from the laboratory of the Commonwealth Bureau of Biological Control in California have

been reared on one or more of the indigenous mealybugs not recorded as host species in last year's report, viz. :—

(*a*) *Pseudaphycus angelicus* on *P. citri.*

(*b*) *P. mundus* on *P. njalensis, P. citri, P. brevipes* and *Ferrisia virgata.*

(*c*) *Pauridia peregrina* on *F. virgata* and *Phenacoccus* sp. nr. *madeiriensis.*

(*d*) *Leptomastix dactylopii* on *P. njalensis, P. citri, P. brevipes, F. virgata* and *Phenacoccus* sp. nr. *madeiriensis.*

(*e*) *Chrysoplatycerus splendens* on *P. citri* and *F. virgata.*

(*f*) *Tetracnemus peregrinus* on *F. virgata.*

(*g*) *Acerophagus pallidus* on *F. virgata,* and *Phenacoccus* sp. nr. *madeiriensis.*

(*h*) *Allotropa* sp. on *P. njalensis, P. citri, F. virgata,* and *Phenacoccus* sp. nr. *madeiriensis.*

(*i*) *Anagyrus fusciventris* on *P. njalensis, P. citri* and *F. virgata.*

(*j*) *Blepyrus saccharicola* on *P. njalensis, P. citri, P. brevipes* and *F. virgata.*

Releases and Recoveries of Natural Enemies.

P. angelicus, P. mundus and *P. peregrina* have reproduced most freely and have been liberated at various stations as follows :—

TABLE 15.

Species.	Adonkwanta.	Akwadum.	Koransang.	Total.
P. angelicus	58,311	59,654	52,099	170,064
P. peregrina	13,566	17,321	32,877	63,764

TABLE 16.

Species.	Bunsu.	Oyoko.	Total.
P. mundus ...	3,700	3,030	6,730

During the eight weeks immediately after the recovery of the single specimen of *P. angelicus* at Koransang reported last year no parasites were liberated at this station. Specimens of *P. njalensis* collected after this interval yielded three specimens of *P. angelicus,* thus demonstrating that it can maintain itself for more than one generation under Gold Coast conditions. There have been no other recoveries of any introduced species during the year.

CHEMICAL CONTROL OF MEALYBUGS.

(1) *Systemic Insecticides.*

In a previous Report it was shown that certain chemicals could successfully be used to kill mealybugs. These chemicals are absorbed into the sap stream of the plant and they are ingested by the feeding mealybugs.

Several commercial preparations are now available and it has become necessary to develop—

1. a simple laboratory screening technique, and

2. a field test for those chemicals passing the screening test.

(1) SCREENING TEST.

At present the method used is to infest plants growing in soil with ten adults *P. njalensis.* These plants are left for seven to ten days to allow ample establishment of the insects before treatment.

As a standard treatment bis-dimethylamino fluorophosphine oxide is used. This chemical has shown a strong toxic action towards mealybugs when used as a systemic insecticide (1). When two other compounds are to be tested seven treatments are used, i.e., Control, Standard 1, Standard 2, XI, X2, YI and Y2. The figures 1 and 2 represent two strengths of the insecticides under test, the one being double the other. Three replications are used and the test appears to show up differences in action very well.

The retransformed figures obtained in one test are shown below.

TABLE 17.

	Time in days.					
	0		5		10	
	Mealybugs.	% kill.	Mealybugs.	% kill.	Mealybugs.	% kill.
Control	258	—	373	—	431	—
X25*	250	—	4·9	98·0	5·0	98·0
X50*	235	—	2·4	99·0	1·1	99·5
Y25 ...	231	—	40·5	82·5	58·7	74·6
Y50 ...	293	—	5·8	98·0	7·2	97·5
S25 ...	285	—	15·7	94·5	1·5	99·5
S50 ...	220	—	3·0	98·6	0·4	99·9

* 25 and 50 refer to concentrations of 25 and 50 p.p.m. on the total weight of soil and seedling.

A statistical analysis of the results showed no significant difference between any of the chemicals at 50 p.p.m. but at 25 p.p.m. chemical Y was significantly less good than the other two.

(1) Nicol J. Nature **169** 120 (1952).

2. Field Test.

In an area where the cacao trees are known to be heavily infested with mealybugs, ten trees are selected for each treatment. The control is divided into two, and one-half (five trees) is cut down and the branches searched for mealybugs or carton nests. These are cut off and placed in containers so that the insects present can be counted later with the aid of a binocular microscope.

Solutions containing 5 per cent. of the active principle are poured into shallow trenches scraped around the base of the trees, the quantity for each tree being assessed from the girth of the tree. Leaf litter is then placed in and over the trench, and the trees left for five weeks.

At the end of five weeks all the remaining trees are cut down and the mealybugs on them are counted as before.

The method is cumbersome and tedious, but it is doubtful if a simpler method can be developed owing to the wide fluctuations in the numbers of mealybugs which are present on the trees and in individual carton tents.

IX. ARBORICIDES.

The work described in previous Reports in connection with the killing of (*a*) diseased cacao and (*b*) forest trees known to be alternative hosts of the virus and vector of swollen shoot disease has been continued.

(*a*) Diseased Cacao.

The large-scale trial, previously referred to, has been completed.

Preparation of trees.

Two methods of application were employed. For one series, the trees were double frill-girdled, the bottom frill being not more than four inches above ground level and the top one about twelve inches higher. For the other series, the trees were felled leaving stumps not more than four inches in height.

Materials used.

Sodium arsenite, aqueous solution, 10, 25, 50 per cent. As_2O_3 (girdled trees).

Sodium arsenite, aqueous solution, 1, 2, 5, 10, 25 per cent. As_2O_3 (stumps).

(1) "Weedicide," aqueous solution, 13 per cent. As_2O_3.

Ammonium sulphamate, aqueous solution, 10, 25, 50, 75 per cent. (girdled trees).

Ammonium sulphamate, aqueous solution, 2·5, 5, 10, 25, 50 per cent. (stumps).

(2) "Atlacide," aqueous solution, 5, 10, 20 per cent. sodium chlorate.

(1) Plant Protection, Ltd., product containing sodium arsenite, 35 per cent. As_2O_3 w/w.

(2) Plant Protection, Ltd., product containing 60 per cent. sodium chlorate with a fire suppressant.

(3) High aromatic oil.
(4) YF 2619, oil solution, 0·1, 1, 5 per cent. acid equivalent.
YF 2619, aqueous emulsion, 0·1, 1, 5 per cent. acid equivalent.
(5) YF 2631, oil solution, 0·1, 1, 5 per cent. acid equivalent.
YF 2631, aqueous emulsion, 0·1, 1, 5 per cent. acid equivalent.
(6) YF 2717, oil solution, 0·1, 1, 5 per cent. acid equivalent.
YF 2717, aqueous emulsion, 0·1, 1, 5 per cent. acid equivalent.
The oil used for making solutions was Shell Technical White Oil.

Results.

Ten mature trees were used for each treatment and results are shown in the following tables:—

TABLE 18.

Double Frill—Girdle.

Material.	Average girth of trees. (in.)	Average quantity of material. (ml.)	Average weight of active ingredient. (grm.)	Condition of trees after treatment.	
				Alive.	Dead.
10% Sodium arsenite	18·7	65·0	6·5	1	9
25% „ „	18·2	71·0	17·5	—	10
50% „ „	20·0	67·5	33·8	—	10
13% "Weedicide"	20·1	70·5	9·2	—	10
10% "Ammate"	18·8	61·0	6·1	2	8
25% „	20·2	63·5	15·9	—	10
50% „	18·9	65·5	32·8	1	9
75% „	17·9	63·5	47·6	—	10
5% "Atlacide"	19·3	53·5	2·68	9	1
10% „	20·3	61·5	6·15	2	8
20% „	18·1	61·5	12·30	—	10
High Aromatic Oil	17·3	133·0	34·4	—	10
YF2619 0·1% aqueous emulsion ...	16·1	64·5	0·065	6	4
„ 1·0% „ „ ...	16·1	59·5	0·60	—	10
„ 5·0% „ „ ...	15·2	53·5	2·68	—	10
„ 0·1% oil solution ...	17·7	56·0	0·056	1	9
„ 1·0% „ „ ...	17·6	65·0	0·65	—	10
„ 5·0% „ „ ...	17·1	53·5	2·68	—	10
YF2631 0·1% aqueous emulsion ...	16·8	56·5	0·057	1	9
„ 1·0% „ „ ...	17·1	62·0	0·62	1	9
„ 5·0% „ „ ...	16·4	57·5	2·88	—	10
„ 0·1% oil solution	16·9	54·0	0·054	—	10
„ 1·0% „ „	17·2	55·0	0·55	1	9
„ 5·0% „ „	18·3	54·0	2·70	—	10
YF2717, 0·1% aqueous emulsion ...	17·2	58·5	0·059	3	7
„ 1·0% „ „ ...	16·7	56·5	0·57	—	10
„ 5·0% „ „ ...	16·3	53·5	2·68	—	10
„ 0·1% oil solution	16·1	52·0	0·052	6	4
„ 1·0% „ „	16·5	52·5	0·53	—	10
„ 5·0% „ „	16·0	53·0	2·75	—	10
Controls (frill girdled only)	18·8	—	—	9	1

(3) Anglo-American Oil Co., Ltd., product. An oil distillate containing 30 per cent. aromatic compounds.
(4) Plant Protection, Ltd., formulation containing 25 per cent. of the acid equivalent of each of the *n*-butyl esters of 2,4-D and 2,4,5-T.
(5) Plant Protection, Ltd., formulation containing 33 per cent. of the acid equivalent of *n*-butyl ester of 2,4-D and 17% of the acid equivalent of the *n*-butyl ester of 2,4,5-T.
(6) Plant Protection, Ltd., formulation containing 33⅓ per cent. of the acid equivalent of *n*-butyl ester of 2,4,5-T.

A further small trial was carried out on trees which forked into two main trunks within about two feet of ground level. It had been found that, when such trees are treated by girdling the single trunk, a strip of live tissue may persist on the inner surface of one or both of the forked trunks. For the present trial the double frill girdle was cut on the single main trunk in the normal way. In addition, one frill was cut on each forked trunk about one foot above the point of forking. Twelve trees were treated with 10 per cent. sodium arsenite solution.

Results are shown in Table 19.

TABLE 19.

Girth of main trunk. (in.)	Girth of forked trunks. (in.)		Height of fork above ground level. (in.)	Quantity of material. (ml.)	Weight of active ingredient. (grm.)	Condition of trees after treatment.
	A	B				
23	13	11	29	100	10	Dead
17	10	10	9	90	9	,,
31	10	17	12	160	16	,,
22	14	10	10	180	18	,,
18	12	9	7	100	10	,,
26	12	14	8	140	14	,,
22	13	12	30	100	10	,,
14	10	11	10	130	13	,,
21	10	13	10	100	10	,,
18	12	10	17	100	10	,,
22	15	12	22	130	13	,,
20	9	12	9	100	10	,,

Results obtained by stump treatment are shown in Table 20.

SUMMARY.

It has been shown that cacao trees can be killed with certain chemicals either by treating the standing tree or by stump treatment after felling.

Work previously reported showed the following materials to have little or no toxic effect :—

Dinitro-sec-butyl phenol (D.N.B.P.).

Dinitro-o-cresol (D.N.O.C.).

Pentachlorphenol.

Potassium ethyl xanthate.

TABLE 20.

Stump Treatment.

Material.	Average girth of trees. (in.)	Average quantity of material. (ml.)	Average weight of active ingredient. (grm.)	Condition of trees after treatment.	
				Alive.	Dead.
1% Sodium arsenite	14·1	65·5	0·66	4	6
2% „ „	14·9	59·5	1·19	—	10
5% „ „	14·0	55·5	2·78	—	10
10% „ „	14·1	63·0	6·30	—	10
25% „ „	17·1	63·0	15·75	—	10
2·5% "Ammate"	13·0	49·5	1·24	2	8
5% „	15·1	67·0	3·35	1	9
10% „	13·7	63·0	6·30	3	7
25% „	13·5	62·0	15·50	—	10
50% „	15·9	51·0	25·50	—	10
5% "Atlacide"	18·9	141·0	4·23	—	10
10% „	18·7	96·0	5·76	—	10
20% „	20·2	123·0	14·76	—	10
High Aromatic Oil	19·1	55·0	14·19	—	10
High Aromatic Oil over whole stump...	19·1	251·0	64·76	—	10
YF2619 0·1% aqueous emulsion ...	17·1	57·0	0·057	—	10
„ 1·0% „ „ ...	18·4	53·5	0·54	—	10
„ 5·0% „ „ ...	18·8	58·0	2·90	—	10
„ 0·1% oil solution	16·4	56·5	0·057	1	9
„ 1·0% „ „	16·7	59·0	0·59	—	10
„ 5·0% „ „	15·7	58·0	2·90	—	10
YF2631 0·1% aqueous emulsion ...	17·5	50·5	0·051	—	10
„ 1·0% „ „ ...	17·2	60·0	0·60	—	10
„ 5·0% „ „ ...	18·8	60·0	3·00	—	10
„ 0·1% oil solution	16·1	59·5	0·060	1	9
„ 1·0% „ „	15·6	62·0	0·620	—	10
„ 5·0% „ „	14·0	62·5	3·13	—	10
YF2717 0·1% aqueous emulsion ...	19·2	64·0	0·064	2	8
„ 1·0% „ „ ...	19·9	54·0	0·54	—	10
„ 5·0% „ „ ...	19·6	56·0	2·80	—	10
„ 0·1% oil solution	13·7	58·5	0·059	4	6
„ 1·0% „ „	13·9	61·0	0·61	—	10
„ 5·0% „ „	13·9	58·5	2·93	—	10
Controls (felled only)	16·2	—	—	7	4

The present work shows the following materials to give a complete kill :—

TABLE 21.

Material.	Minimum concentration for complete kill (per cent.).	
	Standing trees.	Stumps.
Sodium arsenite	13	2
"Ammate"	75	25
"Atlacide"	20	5
High Aromatic Oil	Undiluted	Undiluted
YF2619 (aqueous emulsion)	1	0·1
„ (oil solution)	1	1
YF2631 (aqueous emulsion)	5	0·1
„ (oil solution)	5	1
YF2717 (aqueous emulsion)	1	1
„ (oil solution)	1	1

It is worthy of note that the minimum effective concentration for stump treatment is in most cases considerably less than that for standing trees.

It has not been possible to apply test materials throughout the seasonal stages of tree growth but it should be pointed out that several treatments have been carried out during both the wet and dry seasons with no difference in effect.

(*b*) Forest Trees.

The work previously reported is still in progress. It appears that where these large trees (*Ceiba pentandra* and *Cola cordifolia*) are concerned, death may not be apparent until more than a year after treatment.

However, at this stage, a number of trees have been killed and others are considered unlikely to recover.

It can be stated that the following materials appear to have little or no toxic effect :—

Ceiba:—" Ammate ".
Pentachlorphenol.

Cola:— " Ammate ".
Pentachlorphenol.
High Aromatic Oil.
" Atlacide ".

While some materials are undoubtedly showing marked effects on the trees, the only ones which have given an appreciable kill have been sodium arsenite and growth regulator formulations.

All concentrations of sodium arsenite from 5 per cent. to 30 per cent. have killed *Ceibas* of girth 30–40 feet. With *Cola*, however, and with the exception of one tree, only 20 per cent. and 35 per cent. have been effective.

Formulations of the *n*-butyl and iso-propyl esters of 2,4-D and 2,4,5-T have been used and in a number of instances have given a kill. Since most of the trees are not yet dead but appear to be dying it is not considered advisable at this stage to attempt comparison of formulations.

Meanwhile, in the light of what has been found already, further treatments are progressing.

X. AGRONOMY.

Sub-Stations.

The growth of young cacao on all the sub-stations has been good, with no dry season set-back in August and September, as has been the case in previous years.

Heavy rains in October built up a good reserve of soil moisture and carried the cacao through the dry December to February period with very little check in growth.

A reduction of the cacao stand by gradual and discriminate removal of backward trees, immediately prior to " flush " periods has been carried out without breaking the cacao canopy and thus avoiding the exposure of the soil to insolation.

The control of capsids has become increasingly difficult owing to the size of the trees, but damage, particularly where a closed canopy exists, has been confined to the tips of the branches.

Shade conditions on all sub-stations have reached the happy stage where it has been found possible to remove some of the less beneficial species without exposing the cacao, and considerable shade reduction has been effected by either the complete removal of Rain trees or of some of their main branches by ring-barking.

A number of young trees at Nankese and at Akwadum produced " round pods " and this was considered sufficiently suspicious as to warrant the request of an investigation by the Virologist. No leaf symptoms or swellings have been found in the field and the trees are otherwise apparently healthy.

Akwadum.

Growth of cacao was good on those plots situated on the better soils and planted at the closer spacings. The cacao originally planted at 10 ft. × 10 ft. has not yet formed a canopy and appears to be much more susceptible to capsid attack.

During the year a four-acre plot on light sandy soil was prepared for planting with Upper Amazon seedlings in the 1952 planting season, Amelonado cacao having been a complete failure. As evidence of this only 222 cacao trees had survived from the original planting of 4,350. All Rain trees (*Saman Samanea*) have been cut down on the area and a " salad shade " of Gliricidia and Tree Cassava has been planted to shade the Amazon seedlings when they are planted out as basket plants.

All the cacao trees from the Resistance Trial area were removed during the early part of the year and the land was replanted with West African Amelonado cacao as " seed at stake."

2,277 pods were harvested and given to local farmers for seed.

Nankese.

This farm continues to make excellent progress and large areas are coming into bearing.

There were no cases of swollen shoot disease, but six trees found bearing " round pods " are suspects and are under investigation.

Shade trees have been thinned out and all Oil palms kept pruned back to the central " spear " during the wet season.

1,271 pods were harvested. Capsid damage was negligible.

Kukua.

Growth continued to be excellent on the slopes and in the valleys, and 6,744 pods were harvested, chiefly from these areas.

Swollen shoot disease incidence was confined to three in the " control " portion of the farm and one in the " treated " portion.

Many of the seedlings in the " control " area which were first discovered with swollen shoot disease symptoms in 1948 are still growing vigorously, although showing well marked mosaic in the leaves.

Much of the Rain tree canopy has been reduced by ring-barking a proportion of the main branches. Dense low-growing indigenous trees have also been removed.

Capsid damage was negligible during the year, probably due to the fact that most of the mature cacao in the vicinity of the farm has succumbed to either swollen shoot disease or has been cut down during preparation of the land for food farming.

Adownkwanta.

Growth continues to be much slower on this farm than on those in the drier areas, and although the cacao remains healthy it is much later coming into bearing. Preparations have been made to rehabilitate the half of the farm which had not been protected against capsids or swollen shoot disease, by planting seedlings in baskets for planting out in the coming planting season, by removing damaged tissue from seedlings damaged by capsids and by removing all swollen shoot infected seedlings which had been left for observation.

The incidence of swollen shoot disease was confined to the " control " plot, where 28 infected seedlings were found, 17 of these being in a group some 30 yards from the perimeter.

Capsid damage was less severe than in previous years.

Koransang.

The population of the original mature trees on this farm has been reduced to 206. Of these 130 were coppiced in 1946.

Growth of the young cacao has been very vigorous and only two seedlings were found with swollen shoot disease, although 57 mature and 36 coppiced trees were cut out after having become infected.

Shade has been reduced throughout the plot by ring-barking unwanted trees and pruning the oil palms.

METEOROLOGY.

Monthly and annual rainfall data appear in Appendix 1.

TAFO STATION.

A. Cacao Crop.

1. *Old Station.*

There was no perceptible break between the Light and Main Crop harvests.

All cacao harvested up to the end of August was used for experimental fermentations and for planting on the Station or issue as seed to the Department of Agriculture.

There was a very low incidence of "black pod" disease in the early part of the season and all pods were usable.

The dry weight of marketable cacao harvested during this period has been assessed on the basis of 11·3 pods per lb. of dry cacao.

The percentage of pods discarded was extremely low at 2·5 per cent. compared with the 14-year mean of 12 per cent.

Overall yield per acre of dry cacao was 6·8 per cent. higher than for the previous year, and only 2·1 per cent. lower than the 14-year mean.

The details of delivery of crop are contained in Tables 22 and 23, but full details are lacking for the early part of the season owing to the methods of disposal stated above.

TABLE 22.—*Light Crop.*

Date of picking.	Total pods harvested.	Per cent. pods discarded.	Wet weight in lbs.	Per cent. dry/wet.	Pods per lb. dry.	Pods issued for export and other purposes.
May 15–31 ...	4,435	—	—	—	—	4,435
June 4–19 ...	4,551	—	—	—	—	4,551
„ 27–July 10	2,466	—	—	—	—	2,466
July 13–26 ...	1,109	—	—	—	—	1,109
„ 30–Aug. 11	1,673	—	—	—	—	1,673
Total Minor ...	14,234	—	—	—	—	14,234

TABLE 23.—*Main Crop.*

Date of picking.	Total pods harvested.	Per cent. pods discarded.	Wet weight in lbs.	Per cent. dry/wet.	Pods per lb. dry.	Pods issued for export and other purposes.
Aug. 16–27 ...	13,978	—	—	—	—	13,978
Sep. 5–10 ...	24,027	0·8	5,678·5	40·46	9·51	1,978
„ 12–21 ...	35,780	1·3	8,459·6	41·59	9·78	914
„ 28–Oct. 10	51,916	2·6	12,884·4	36·12	10·42	2,080
Oct. 15–Nov. 1	76,727	2·5	16,195·3	40·72	10·82	4,238
Nov. 8–26 ...	78,787	3·2	14,141·6	40·69	12·29	5,632
„ 30–Jan. 3	119,413	3·3	22,411·0	42·12	12·03	1,900
Jan. 5–19 ...	49,997	2·8	8,919·9	43·94	12·40	—
„ 22–30 ...	4,838	11·3	726·0	43·52	13·52	20
Total Main ...	455,463	2·5	89,406·3	40·81	11·32	30·740
1951/52 Total...	469,697	2·5	89,406·3	—	—	44,974
1950 51 Total...	452,677	3·4	87,799·5	—	—	18,213

Comparative data for the current season, the previous season and the 14-year mean appear in Table 24.

TABLE 24.

Light/Main Crop Seasons.

Period.	Total pods harvested.	Per cent. pod discards.	Wet wt. of beans lb.	Per cent. dry/wet.	Pods per lb. dry cacao.	Yield per acre in * lb. dry.
Light						
14-Year Mean...	57,738	16·7	10,718·0	37·57	11·5	61·51
1951/52 ...	14,234	—	—	—	—	19·10
1950/51 ...	44,924	5·6	9,577·3	37·31	10·9	61·1
Main						
14-Year Mean...	510,651	11·4	92,582·6	41·75	11·6	585·50
1951/52 ...	455,463	2·5	89,406·3	40·81	11·3	614·20
1950/51 ...	407,753	3·2	78,222·2	41·74	11·6	532·6
14-Year Mean Light/Main ...	568,390	12·0	103,300·5	41·31	11·6	647·01
1951/52 ...	469,697	2·5	89,406·3	40·81	11·3	633·30
1950/51 ...	452,677	3·4	87,799·5	41·26	11·6	593·7

* Includes calculated dry weight from pods used for seed and experimental purposes.

The distribution of yields from 224 one-quarter acre and 31 one-sixteenth acre plots is shown in Table 25.

TABLE 25.

Distribution of yields from 224 *one-quarter* + 31 *one-sixteenth-acre plots.*

Yield Class.	Percentage of total number of plots in each class.				
	1947/48	1948/49	1949/50	1950/51	1951/52
0— 200	13·4	5·36	5·80	4·91	4·46
201— 400	38·0	13·84	20·09	20·09	13·84
401— 600	36·2	24·11	30·36	34·38	25·89
601— 800	8·9	24·55	25·00	22·77	30·36
801—1,000	3·1	18·30	16·07	12·05	16·52
1,001—1,200	0·4	8·93	2·23	4·46	7·14
1,201—1,400	—	4·46	0·45	1·34	1·34
1,401—1,600	—	0·45	—	—	0·45
Highest plot yield in lb. per acre	1,051·48	1,485·60	1,252·84	1,381·32	1,461·32
Lowest plot yield in lb. per acre	Nil.	3·68	1·64	8·64	Nil.

The modal class has risen from 401–600 lbs. per acre in 1950–51 to 601–800 in 1951–52.

The percentage of plots yielding more than 400 lbs. per acre rose from 75 per cent. in the previous year to 82 per cent. in the current season.

Warty pods.

The position with regard to "Warty Pod" incidence is practically identical with that of the previous year.

Tree Mortality.

The number of trees removed during swollen shoot disease treatments was 393 and of these 23 were suspects, 88 seedlings were also found with virus infection, an increase which may be attributed to the more complete canopy which has developed in much of the seedling cacao.

Trees lost from senility, tornado damage, etc., totalled 195.

2. *Square Mile.*

Yield data for the mature cacao on the Square Mile are omitted as the assessment of the acreage of the large number of irregular shaped and sized cacao pockets left after cutting out is virtually impossible from present maps.

The whole area is in the course of being resurveyed and a more accurate plan of the area will give valuable information, particularly with regard to more economic use of the land available for experimental purposes.

B. Field Experiments.

Cacao on all experimental areas has continued to make good progress and the growth of forest tree seedlings has been encouraging.

On the experimental areas planted in 1947 it has been possible to select and remove those species of indigenous shade trees which it is felt will compete with the cacao at canopy height. Capsid damage has been kept within reasonable bounds by applications of D.D.T. emulsion when and where incipient damage has been seen, in addition to the routine overall applications. There has, however, been a limited amount of damage to the tops of the larger seedlings, presumably by adult capsids moving in from old cacao.

Pod production in the earlier planted experiments has been too low and too patchy to use in assessing treatment differences on a basis of yield.

The Uniformity Trial.

Growth continued to be slow and the plants are still a long way from forming a closed canopy. Overhead shade conditions are good. 14 seedlings produced 48 pods.

The Establishment Trial.

All remaining Banana stools were removed from the area leaving the *Gliricidia* and a good stand of young forest trees to shade the cacao, the basket seedling treatment is still outstanding and produced over half the 65 pods harvested during the year.

The Second Establishment Trial.

The bush traverses have been selectively thinned leaving only tree seedlings to develop. In the other treatments growth has been good. A full stand has been maintained throughout by replanting vacancies with basket seedlings. 57 such vacancies occurred, distributed fairly evenly between treatments.

An analysis of the data from a count of trees suffering from capsid damage showed no significant difference due to establishment treatments.

The Spacing Trial.

Shade conditions have improved and the cacao is in better condition than hitherto. An analysis of yields from this experiment was again considered impracticable owing to the low numbers of pods plucked.

Thinning Trial.

Seedlings in the closely spaced treatments have again been thinned, those in the routine thinning treatment now being spaced at 4 ft. × 4 ft. Growth of individuals is still apparently not so good as in the trees in the plots planted at 8 ft. × 8 ft.

The Upper Amazon Spacing Trial.

General health and growth has been excellent in this area and in the extension of five acres planted five months later.

The half-plots subjected to the pruning treatment have yielded 139 pods compared with 82 from the unpruned trees, but this probably means little at this early stage of growth.

Pruning appears to have had the effect of inducing a very heavy growth of secondary " water shoots " and it remains to be seen whether or not this continues to be the case as the trees become mature and form a closed canopy.

The seedlings in the 8 ft. × 8 ft. spacing treatment have, in the more advanced areas, almost met in the rows.

Herrania Multiplication Plot.

The trees in this plot flowered heavily twice during the year but set very few pods at the first flowering.

There was a good crop of pods of up to 10 per tree from the second flowering, but due to the depredations of small rodents, very few reached maturity. Barium carbonate was used as a poison in banana baits and appeared to lessen the damage in a limited area, but A.N.T.U. (alpha-naphtha-thio-urea) seemed to be consumed with no ill-effects. A number of small rats were trapped in home-made box traps and three distinct species were represented.

Transplanting Experiments.

The experiments were laid down in the nursery beds during February, 1951, as indicated in previous reports (Quarterly Report, Jan.–March, 1951 : Annual Report, 1950–51), and transplanting was carried out in June, 1951, according to the treatments already described. In addition, a further experiment, consisting of the three-stem treatments (control, leaves removed, stumping to 4 in.), replicated six times in a randomised block design, was planted. Material from Oyoko Cocoa Station as issued to cocoa farmers formed the planting material for this experiment.

Counts of dead plants were made at monthly intervals on all experiments and the table below indicates the results to date (March, 1952). The small effect of superphosphate has so far been negligible and the results for T.E.I. and T.E.II are shown as means over the two phosphate treatments. Significant effects noted from the table are—

(*i*) A reduction in losses due to leaf removal compared with stumping at W.A.C.R.I., but no benefit derived from leaf removal over no treatment.

(*ii*) At Akwadum the lowest loss is again shown by no treatment, this value being significantly smaller than either leaf removal ,, or stumping.

(*iii*) The situation is reversed in T.E.III, but overall losses are very much higher with these plants.

It may be stated in general that with the careful hand-fork lifting of the younger plants as at W.A.C.R.I. and Akwadum (four months as compared with seven months at Oyoko) any form of stem treatment appears to produce no advantage, on the basis of a single year's experimentation. Further work is in progress to test this effect critically, with and without careful removal from the nursery beds.

TABLE 26.

Transplanting Experiments, 1951.

Table showing percentage losses (angular transformation) after first dry season (March, 1952).

Experiment No.	Site.	Plant material origin and age.	Method of uprooting	Delay in planting.		Treatment means (averaged over phosphate and no phosphate for T.E.I and T.E.II.			S.E. of mean.
						Stem whole.	Leaves removed.	Stumped to 4 in.	
T.E. I	W.A.C.R.I. Square Mile	W.A.C.R.I. Valley bottom clay nursery beds. 4 months.	Hand-fork lifting. Soil retained around roots.	Average ½ hour.	Angles	17·5	17·1	24·2	±2·31
					Per cent.	9·0	8·6	16·8	
T.E. II	Akwadum Sub-Station	Akwadum. Koforidua series (eroded). Sandy nursery bed. 4 months.	Hand-fork lifting. Little soil retained around roots.	Average ½ hour. Rainfalling at times of transplanting.	Angles	19·2	29·2	40·6	±2·90
					Per cent.	10·8	23·8	42·3	
T.E. III	W.A.C.R.I. Square Mile.	Oyoko Cocoa Station. As issued to farmers. 7 months.	Hand pulling. No soil retained around roots.	Up to 2 hours including 15 miles transport.	Angles	62·7	35·5	34·6	±2·00
					Per cent.	79·0	33·7	32·3	

Potting Material from Various Levels.

Hitherto potting material used for basket seedlings has consisted of the top two or three inches of soil from any available site where there is reasonably high organic matter content and such a method has proved extremely wasteful, leading to temporary spoilation of large areas.

An experiment, using soil from the top 6 inch, 9 inch, 12 inch and 15 inch strata, in each case well mixed, as potting material, was laid down as a 4 ft. × 4 ft. latin square, each treatment consisting of 12 baskets in which cacao seeds were planted in early November. There was no significant difference in germination of the seeds.

The plants were lifted and weighed at the end of March showing no significance between the growth in the different soils.

There was, however, a gradual trend in favour of the deeper soils as is shown in the accompanying Table of Means :—

TABLE OF MEANS (*wt. per plant at five months*).

Soil from top.	6 in.	9 in.	12 in.	15 in.
Mean wt. per Plant (gms.)	6·14	7·10	7·39	7·68

Significant Difference (P = 0·05) = ± 1·90.

There is an advantage in using the deeper soils in so far as they are more retentive of moisture and not so friable and likely to shake loose from the roots of the seedlings during transportation.

The Third Establishment Trial.

This experiment was laid down during the year to investigate the possibility of using an economic crop as a component of the cacao establishment shade treatment.

The treatments used are :—

(*a*) Tree Cassava planted as stakes in September with volunteer or planted Cocoyams as ground cover.

(*b*) Plantains planted in September and Cocoyams as in (*a*).

(*c*) Maize planted September and March, Edible Cassava interplanted in the rows of maize in March.

There is an overall planting of *Gliricidia maculata* as semi-permanent shade at 10 ft. × 10 ft. Cacao will be planted in all plots at 10 ft. × 5 ft. within narrow bush traverses, left between the food crop rows, to serve as reservoirs for forest tree regeneration.

Only senile indigenous trees or those unsuitable as a canopy for the cacao were removed.

The first crop of maize failed, owing to overshading by the forest trees, there being only 49 cobs from 2,800 square yards of land under this treatment.

All other crops have been successfully established.

Performance of Cacao on Different Soil Types.

The replicated twelve-tree plots on five of the soil types represented on the W.A.C.R.I. Old Station have been recorded as already indicated (Quarterly Report, Jan.–March, 1951), but subsequent examination of the original soils map shows that some plots have been wrongly sited according to soil type. Analysis of the consequent figures therefore becomes a more complex procedure and final results for the year under review are not yet available.

Sampling Survey for Forecasting of Cacao Yields.

Regular observations along the lines laid down in last year's report have been made but analysis of the relevant data is incomplete.

C. Swollen Shoot Control.

Table 27 summarises the results of the campaign to keep the swollen shoot disease under control on the Old Station.

TABLE 27.

Month.	New outbreaks.	Trees destroyed.		Total.
		New outbreaks.	Old outbreaks.	
1951				
April	9	18	19	37
May	6	11	18	29
June	6	11	49	60
July	5	7	50	57
August	5	6	63	69
September	7	8	33	41
October...	4	4	31	35
November	2	2	10	12
December	2	5	10	15
1952				
January	3	3	12	15
February	3	4	3	7
March	—	—	16	16
Total 1951/1952 ...	52	79	314	393
Total 1950/1951 ...	57	143	274	417

The average number of trees per " new outbreak " was much lower than in the previous year (1·5 c.f. 2·5). Reinspection and treatment figures for the Square Mile are given in Table 28.

TABLE 28.

Cacao destroyed during treatment—Square Mile.

Section.	April–June.	July–Sept.	Oct.–Dec.	Jan.–Mar.	Total.
A	208	295	296	84	883
B	224	118	131	108	581
C	83	*3,867	103	137	4,190
D	74	82	76	31	263
Total ...	589	4,362	606	360	5,917

* Cut out from abandoned mealybug observation plots.

Of the trees cut out 3,664 were diseased, 1,304 were contact trees and 949 were suspects.

D. Cacao Fermentation Investigations During the Year.

1. A report has been made to the 1951 London Cacao Conference where some of the factors affecting the process of cacao fermentation as observed in experiments with 20-40 lb. batches of wet cacao were indicated. These may be briefly summarised :—

(i) *Degree of ripeness of the pods.*

With W.A.A. this has a marked effect on fermentation, in that pods rather riper than those normally harvested produce cacao with a lower percentage of purple beans and a higher percentage dry/wet weight. There is some degree of association of these characteristics with the percentage of reducing sugars in the pulp.

(ii) *Time between harvesting and breaking.*

Pods have been stored for one, two, three and four days, and it would appear that the optimum time is approximately 2½-3 days, on the basis of limited experimentation only.

(iii) *Varietal differences.*

These have been examined with particular reference to the differences existing between W.A.A. and " Upper Amazon Types," and also the various selections within the latter. The general conclusion is reached that U.A. types are much more difficult to ferment satisfactorily as indicated by a slower rise in temperature and a consistently higher percentage of purple beans which is not reduced by treatments that are effective with W.A.A.

(iv) *Exposure of the beans to the atmosphere prior to fermentation.*

Increased early fermentation temperatures are observed when the beans have been exposed, and there is a trend towards a slight reduction in purple bean percentage.

(v) *Frequency of turning.*

The normal practice of 48-hour turning appears quite satisfactory, but extensive tests have not yet been made with less frequent turnings.

(vi) *Length of fermentation period.*

When extended to eight days is effective in reducing the purple bean percentage in W.A.A. but is conducive to the production of mouldy beans, and local opinion considers the beans lacking in flavour.

(vii) *Rate of drying.*

Slow drying during the early stages appears desirable but is much better achieved by total exposure on a solid surface than by a restricted exposure on a slatted surface. Later observation seems to indicate that drying procedures may require modification during the " harmattan " period, when shade drying has given beneficial results.

(viii) *The addition of " Fermentation Aids."*

Palm wine, and a 5 per cent. " Golden Syrup " solution were added at 0 and 48 hours and the only marked effects noted were a temperature depression by the late additions, and subsequent increases in purple bean percentages.

(ix) *Additional heat as supplied by the " Solar Fermentary."*

The overall effect on fermentation temperatures may be described as a slowing down of the heating phase, followed by a blanketing effect when diurnal cooling-off takes place. The final product from solar fermentation has been judged locally as not inferior to bulk fermented W.A.A. In contradistinction to results obtained by MacDonald, turning the mass appears to be desirable.

2. *Basket fermentation experiments carried out with the co-operation of the Gold Coast Department of Agriculture.*

As indicated above, previous experimental evidence has pointed to the fact that one of the major factors affecting the percentage of purple beans in a sample of fermented Amelonado cacao is the condition of the pods at the time of breaking, as determined by (*i*) degree of ripeness, and (*ii*) length of time of storage of the unbroken pod after harvesting. A series of experiments designed to

investigate the full effect of these two factors over a wide range of conditions was therefore carried out with the full co-operation of the Gold Coast Department of Agriculture.

Pods from four successive days' harvests were sorted into under-ripe, ripe, and over-ripe lots and fermented separately in baskets for six days with 48-hourly turning. Details of wet and dry bean characteristics have been recorded; in certain cases temperatures were taken at 24-hourly intervals, and at W.A.C.R.I., analyses of original pulps have been made with the co-operation of the Senior Chemist. Results are now complete and await statistical analysis.

3. *Preparation of Upper Amazon and Gold Coast Selections for quality assessment by expert and local panels.*

During the course of the past main-crop season, 31 Upper and Lower Amazon cacao types and 28 Gold Coast selections (mainly Second P.T.A. material) have been fermented in varying sized batches using the muslin-bag technique modified to avoid pulp contamination from the other mass. The modification consisted of putting a layer of banana leaves on the bulk cacao onto which the bags were placed and themselves covered with a heap of banana leaves. It was possible to ferment each type three times and, as far as was consistent with the harvesting, selections of a group, *e.g.,* '' Nanay,'' were fermented at the same time. Amelonado controls were also fermented in the same way.

Data recorded was such as to give full information about wet and dry bean size, recovery rates, quality and analysis as used by the Gold Coast Produce Inspection Division, and determinations of purple and wrinkled bean percentages. Overall the Amazon types show higher purple bean percentages than the Gold Coast selections, but considerable improvement is shown on previous fermentations. The range of variation is wide and is generally above the Amelonado controls. Gold Coast selections on the other hand show much more promise both in purple bean percentage and bean size.

4. *Quality of bulk Amelonado cacao.*

Records have been kept during the past season of the wet and dry bean characteristics of Square Mile and Old Station cacao, with a view to determining seasonal changes in bean size and quality and any correlations which may exist between these factors.

5. In addition, subsidiary investigations into cacao preparation have included a bean storage experiment, modifications of the solar fermentary to increase available heat supplies, a shade-drying experiment, and work in collaboration with the Chemist to examine pulp changes during the fermentation of different cacao types.

E. Tafo Station : Maintenance and General.

Cacao Areas.

A large number of economic forest tree seedlings obtained from the Forestry Department were planted throughout the mature cacao and the survival rate has been much better than that of the young basket seedlings used in previous years.

The principle of replanting all gaps in the cacao, caused by casualties, with cacao seedlings in baskets, has been maintained.

Seedling population in the replanted areas has been reduced by judicious thinning. Normal " chupon " selection was carried out and all young cacao and " chupons " were painted regularly with D.D.T. as a capsid control measure.

The 5th Progeny Trial Area which was under young cacao, badly " blasted " by capsids in the early years, was coppiced to four inches from ground level.

There has been a heavy growth of " chupons " and selective thinning will be undertaken to leave three shoots per tree, the stumps being " earthed up " to promote root formation.

Nurseries.

During the year 5,100 Amelonado and 1,250 Amazon seedlings were raised in baskets.

1,650 seedlings of Herrania have also been raised. Seed of indigenous forest shade trees has been collected and sown as available and the nursery is well stocked with a good selection of seedlings for use in shade regeneration.

Food Crops.

Two crops of maize were grown, both being very badly infected with rust.

Vegetable production fell to approximately 4,000 lbs.

F. Meteorology.

Meteorological data is given in Appendix I.

APPENDIX I—METEOROLOGICAL DATA

A. Tafo Station

(*i*) *Monthly Rainfall (in inches) and number of wet days (April 1951 – March 1952)*

	1951 April	May	June	July	August	Sept.	October	Nov.	Dec.	1952 Jan.	Feb.	March
Rainfall in inches	2·91	6·26	8·09	8·01	2·17	6·06	17·33	5·21	—	2·00	1·52	10·39
Number of wet days	12	13	14	15	13	15	28	10	—	3	7	12

Tafo Station

(*ii*) *Data for 1951 compared with 14-year Means*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum 14-year mean	91·4	93·6	93·4	93·4	92·1	89·4	88·9	69·2	88·0	89·8	90·5	90·5
„ „ „ 1951	93	94	93	93	93	90	88	86	87	89	90	92
Lowest Shade Minimum 14-year mean	60·1	61·4	65·8	66·0	66·6	66·4	66·9	65·7	66·5	66·6	65·1	62·8
„ „ „ 1951	66	60	67	66	65	67	67	67	69	69	68	66
Mean Relative Humidity 14-year mean (9.00 G.M.T.)	86·0	83·8	81·6	81·2	81·8	84·6	85·7	87·8	84·7	82·9	81·6	84·0
Mean Relative Humidity 1951	85·9	84·6	81·6	82·1	83·1	83·7	86·4	86·8	86·4	86·9	83·6	86·1
Mean Relative Humidity 14-year mean (15.00 G.M.T.)	53·6	50·8	54·2	57·7	61·8	67·2	68·4	60·0	70·5	69·5	65·1	61·0
Mean Relative Humidity 1951	58·1	58·8	62·4	61·5	67·1	71·7	73·7	77·0	70·0	77·1	66·4	59·0
Rainfall in inches 14-year mean ...	1·53	3·78	5·78	5·82	7·15	8·27	5·64	2·79	5·85	8·54	5·32	2·56
„ „ „ 1951	0·29	5·48	4·45	2·91	6·26	8·09	8·01	2·17	6·06	17·30	5·21	—
Number of wet days 14-year mean ...	3·4	7·3	11·6	11·2	13·5	18·3	13·3	13·1	13·6	17·9	11·2	6·2
„ „ „ 1951	2	9	8	12	13	14	15	13	15	28	10	—

Tafo Station

(*iii*) *Annual rainfall 1938–1951*

1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	14-year Mean.
55·33	84·96	56·92	56·59	59·45	69·09	49·2	68·87	47·03	67·30	66·99	71·81	63·47	66·23	63·03

B. Sub-Stations

(*i*) *Monthly Rainfall in Inches for the Year 1951.*

Station	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total
Akwadum	0·34	1·26	11·08	4·54	8·19	13·07	5·96	2·17	12·24	15·95	4·02	—	78·82
Nankese	0·28	3·04	11·04	2·78	9·13	6·18	3·17	4·66	3·06	13·35	2·86	0·11	59·66
Koransang	2·83	1·67	7·60	4·14	11·00	6·14	4·78	2·96	4·67	23·00	4·28	0·13	73·20
Kukua	2·04	1·46	7·50	3·37	10·83	3·97	6·52	2·44	2·09	17·10	3·35	—	60·67
Adownkwanta	0·28	4·55	4·85	6·84	5·89	7·79	5·29	1·81	7·23	17·06	7·26	0·55	69·40

(*ii*) *Annual Rainfall Compared with Preceding Year*

Year.	Akwadum	Nankese	Koransang	Kukua	Adownkwanta
1950	47·80	57·01	48·21	42·08	60·79
1951	78·82	59·66	73·20	60·67	69·40

APPENDIX II.

PUBLICATIONS.

Strickland, A. H. ...	The Entomology of Swollen Shoot of Cacao. I.—The Insect Species Involved, with Notes on their Biology. Bulletin of Entomological Research, Vol. 41, Part 4, 1951.
Todd, J. McA.	An Indigenous Source of Swollen Shoot Disease of Cacao. Nature, Vol. 167, 1951.
Strickland, A. H. ...	The Entomology of Swollen Shoot of Cacao. II.—The Bionomics and Ecology of the Species Involved. Bulletin of Entomological Research, Vol. 42, Part 1, 1951.
MacLean, J. A. R. and Wickens, Robert.	Application of an Incomplete Block Design to the Assessment of Quality in Cacao. Nature, Vol. 168, 1951.
MacLean, J. A. R. and Wickens, Robert.	The Assessment of Cocoa Quality by Local "Taste Panels." Cocoa Conference Report, 1951.
MacLean, J. A. R. and Wickens, Robert.	Small-Scale Fermentation of Cocoa. Cocoa Conference Report, 1951.
Posnette, A. F. and Todd, J. McA.	Virus, Diseases of Cacao in West Africa. VIII.—The Search for Virus-Resistant Cacao. Annals of Applied Biology, Vol. 38, No. 4, 1951.
Nicol, John	Systemic Insecticides and the Mealybug Vectors of Swollen Shoot Virus of Cacao. Nature, Vol. 169, 1952.
Benstead, R. J. ...	Cacao Re-establishment. London Cacao Conference Report, 1951.
West, J.	Progress of Research at W.A.C.R.I. London Cocoa Conference Report, 1951.
West, J.	Progress of Research at W.A.C.R.I. on Systemic Insecticides Carried out with Pest Control Limited. London Cocoa Conference Report, 1951.

APPENDIX III—FINANCIAL STATEMENT.

WEST AFRICAN CACAO RESEARCH INSTITUTE.

Balance Sheet as at 31st March, 1952.

LIABILITIES.	£ s. d.	£ s. d.
Surplus and Deficit Account:—		
Surplus		1,477,557 9 7
Depreciation Fund:—		
Motor Vehicles	2,885 5 10	
General Equipment	2,078 13 4	4,963 19 2
		£1,482,521 8 9

ASSETS.	£ s. d.	£ s. d.
Buildings:—		
Value as at 31st March, 1951	264,579 15 8	
Additions during the year	10,581 6 8	
	275,161 2 4	
Less: Amounts written off	275,161 2 4	—
Furniture and Equipment:—		
Value as at 31st March, 1951	25,320 11 9	
Additions during the year	1,647 16 6	
	26,968 8 3	
Less: Amounts written off	26,968 8 3	—
Sundry Debtors:—		
Staff Advances	5,492 9 4	
Staff Subsidies	633 2 6	
Gold Coast Government	115 15 10	
Nigerian Government...	2,121 9 3	8,362 16 11
Stores at Cost:—		
Timber	125 5 6	
Construction	1,375 1 6	
General	260 11 8	1,760 18 8
Investment Account:—		
Investments at Book Value ... ... (Market value £1,121,881 13s. 6d.)		1,380,700 8 0
Post Office Savings Bank Deposit		4,963 19 2
Cash:—		
In Hand—Imprest Account	200 0 0	
Bank of British West Africa Limited ...	46,214 19 3	
Joint Miscellaneous Fund	40,000 0 0	
Crown Agents for the Colonies	318 6 9	86,733 6 0
		£1,482,521 8 9

SGD. ALAN PICKLES, AG. DIRECTOR.
SGD. G. H. NEAL, SECRETARY.

We have audited the above Balance Sheet of the West African Cacao Research Institute with the books and vouchers of the Institute and have obtained all the information and explanations that we have required. In our opinion and subject to our Report of even date attached hereto this Balance Sheet sets forth a true and correct view of the financial position of the Institute as at 31st March, 1952, according to the best of our information and the explanations given to us and as shown by the books of the Institute.

SGD. CASSLETON ELLIOTT & CO.,
Auditors.

ACCRA,

Waterlow & Sons Limited, London and Dunstable.